

Bubbles and Acoustic Communications Experiment (SPACE08): Acoustical and Physical characteristics of Diffuse Bubble Plumes

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LONG-TERM GOALS

The scientific rationale for this project is that current underwater acoustic communication techniques fall far short of what is needed in terms of the data rates, the range of environments and operating conditions, and levels of covertness at which reliable communication links can be established. For example, communications in very dynamic environments (e.g., surface scattered environments in rough weather, communications at depth and speed for submarines) or at low SNRs as required for covert communications are areas where progress is still needed. To bridge the gap between current capabilities and future requirements, an experiment was conducted at Martha's Vineyard Coastal Observatory (MVCO) in the fall of 2008 by a team of investigators with expertise in physical oceanography, underwater acoustics, signal processing, information theory and coding, practical modem development, Navy CONOPS and assets, and in the use of autonomous and distributed systems.

The main goal of this particular project is to investigate the acoustical and physical characteristics of upper ocean bubble plumes from generation to dissolution, especially as they affect the acoustical environment. In-situ and remote acoustical measurements of bubbles, turbulence and whitecaps were combined with ACOMMS experiments run separately by Jim Preisig (WHOI) and Grant Deane's (Scripps) α -plume investigation, so as to permit direct integration of modeling and analysis. This particular project is a collaborative effort between the Institute of Ocean Sciences (Vagle) and University of Rhode Island (David M. Farmer).

OBJECTIVES

The project objectives are to answer the following questions;

(1) how do we use forward scattered 120 kHz acoustic signals to infer the contribution of turbulence and bubbles to propagation fluctuations? Conversely, how do we exploit the propagation measurements to separate out the natural variability due to turbulence and bubbles from ACOMMS signals of interest? Given the contribution of turbulence and bubbles, how do we characterize the resulting variability so as to allow the optimization of acoustic communications algorithms?

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- (2) How does surface turbulence (including Langmuir circulation) and bottom boundary layer turbulence influence the distribution of bubbles in the water column, with corresponding effects on propagation?
- (3) How does the bubble size distribution depend on wave breaking, turbulence, Langmuir advection and bottom boundary layer turbulence?
- (4) Can we use ambient noise as a surrogate for inferring acoustic characteristics of the upper ocean boundary layer? Is the acoustic intensity and spectrum of the noise source related to whitecap speed, dimensions and other properties?

APPROACH

The following measurements were made during the SPACE08 experiment in October 2008 at the Martha's Vineyard Coastal Observatory (MVCO) at Woods Hole Oceanographic Institution (WHOI) (Time lines for each instrument are shown in Figure 1):

To study volume acoustic fluctuations and turbulence we deployed a scintillation system consisting of two masts with four 120 kHz transducers on each, separated by 40m. Reciprocal 20Hz transmissions will allow separation of scalar and vector components. Two 100 kHz sidescan sonars and two 50 kHz vertical sonars deployed only operated for a short time due to brownout conditions and underwater connector problems on the tower. However, the vertical bubble field was captured throughout the experimental period with a 300 kHz RDI ADCP deployed on the seafloor in the experimental area (Figure 2.) This instrument also gives the depth dependent current field and is being used to determine the horizontal extent of the bubble plumes. The local sound speed field was obtained from a recording Seabird 19plus CTD. The oxygen and nitrogen content (required for modelling of bubble plume evolution) was monitored using a combination of an oxygen sensor and a gas tension device attached to the Seabird 19plus CTD mounted on one of the sonar tripods (Farmer et al., 1993; McNeil et al., 1995). A wave following float was tethered to a horizontal mooring attached to the MVCO tower and equipped with a conductivity sensor for air-fraction measurements in dense bubble plumes at a depth of 0.5m and two acoustical resonator (Farmer et al., 1998; Vagle and Farmer, 1998) systems deployed at depths of 0.7 and 1.5m for lower air-fraction, diffuse plumes, bubble size distributions. The float was also equipped with two salinity and temperature sensor pairs at 0.5 and 1.7m for detailed observations of the local sound speed field. Some ambient sound measurements were acquired with two broadband (40-25,000 Hz) hydrophones deployed on two tripods during periods when power was available. Finally, five internally recording RBR TR-1050 thermistors were deployed on the acoustical tripods throughout the experimental period. These instruments sampled the temperature field at several depths every 1-3 seconds.

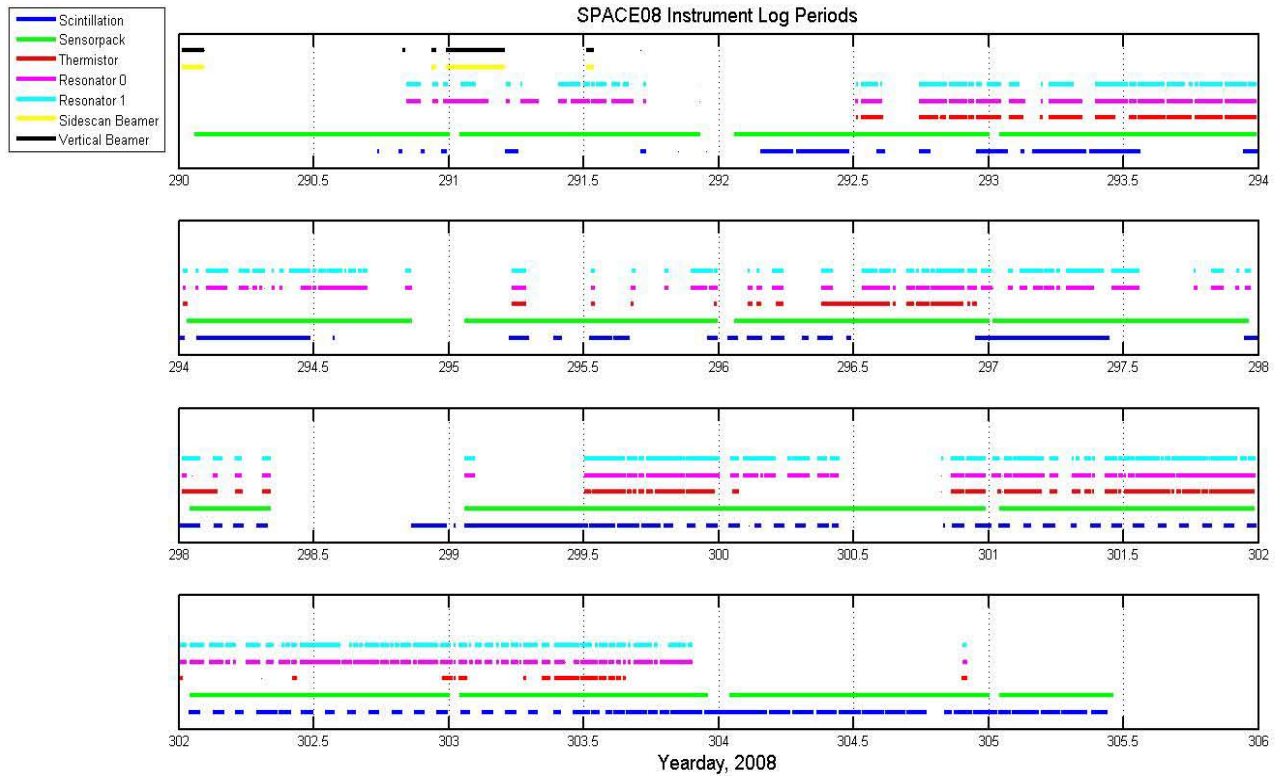


Figure 1. Time lines for different IOS sensors deployed during the October 2008 SPACE08 experimental period. The 120 kHz scintillation system (blue line) was operated whenever the tower power budget allocation allowed. The sensorpak data (green line) is made up of air-fraction data at 0.5m as well as salinity and temperature data at two depths (0.5 and 1.7m), all sampled at 2Hz. A separate thermistor (red line) was recording whenever the upper acoustical resonator (0.7m) (purple line) was operating. A second acoustical resonator was operating at 1.5m (light blue line). The 100 kHz steerable sidescan sonar system (yellow line) and the vertical 50 kHz sonars (black line) failed shortly after deployment due to brownout conditions on the tower and subsequent connector problems. In addition a CTD with O₂ and N₂ sensors and a 300 kHz ADCP operated continuously throughout the experimental period.

WORK COMPLETED

All the equipment was deployed at the MVCO during the second week of October 2008. Initially the instrumentation worked as planned, but as more and more equipment was connected to the tower power supply, equipment started to fail. However, after modifications to the power supplies and the introduction of run scheduling, the experiment proceeded from October 16 to October 30, when the recovery stage started.

All the data collected have been calibrated and parsed into data bases encompassing times when the different sensors were operating. Figure 2 shows the bubble field at a depth of 7m as well as windspeed as obtained from MVCO, showing the good agreement between the bubble field and the

wind forcing. In Figure 3 the corresponding backscatter strength for a four day period show that the bubble field extends from the surface to the seafloor when the windspeed exceeds approximately 8m/s.

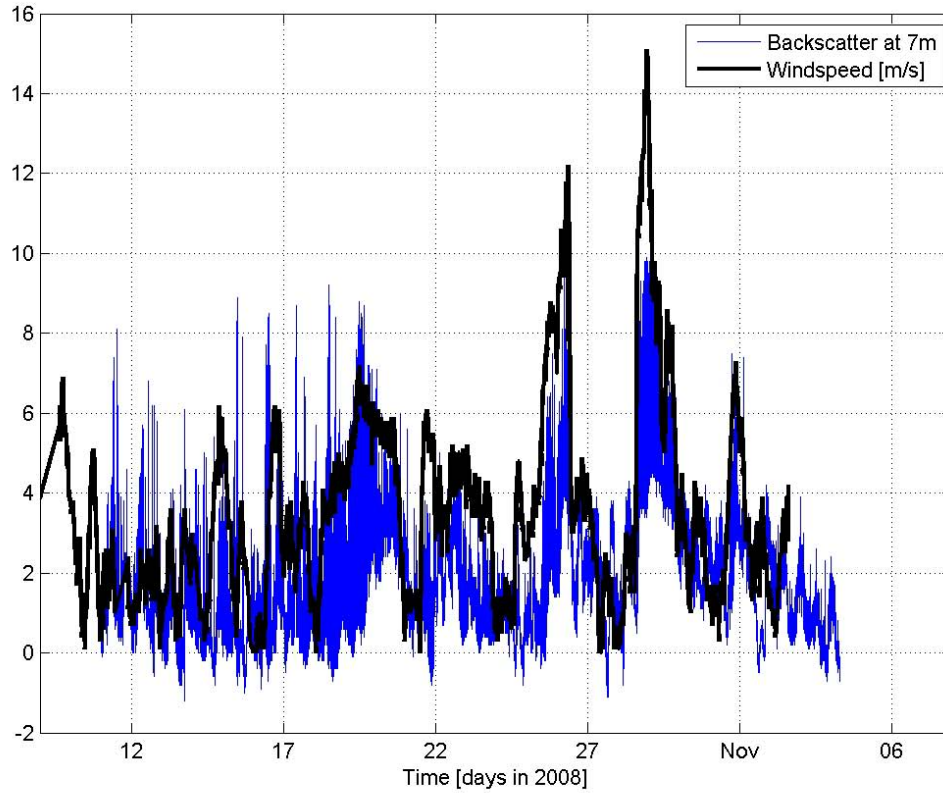


Figure 2. Relative acoustical backscatter strength at 300kHz at a depth of 7m (blue line) plotted with windspeed [m/s] for the experimental period of SPACE08 at MVCO. These backscatter measurements combined with bubble size distributions to be calculated from the surface following float will be used to calculate the effects of these bubbles on acoustical propagation at different acoustical frequencies.

WORK IN PROGRESS

The data set described above is presently being used in an attempt to reach the objectives listed earlier. The 300kHz bubble plume backscatter data, combined with advection rates and resonator bubble size distributions are being used to calculate the effects of these bubbles on sound propagation. These estimates will be compared against the forward scattered 120kHz scintillation measurements obtained here as well as used to interpret the ACOMMS measurements obtained by Preisig. Finally, we want to use our observations to increase our understanding of the role of turbulence in defining the bubble field and its role on sound propagation.

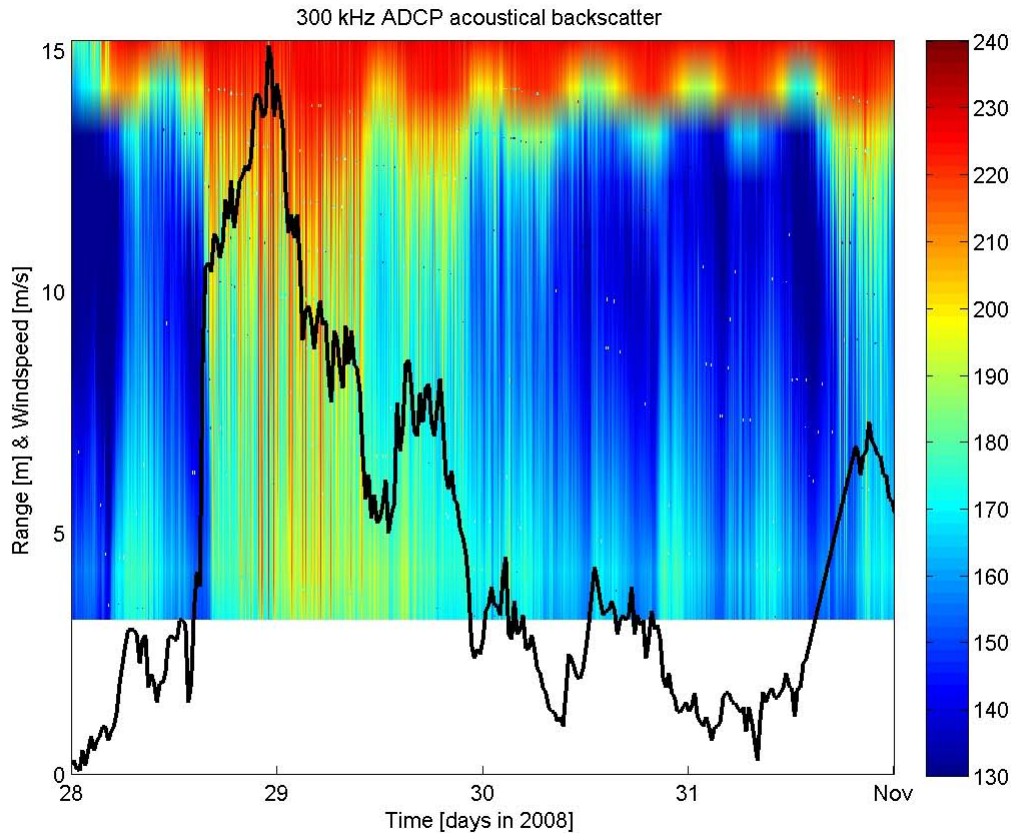


Figure 3. *Relative acoustical backscatter strength at 300kHz shown as function of depth for a four day period during the SPACE08 experiment. The windspeed as observed at MVCO is shown in black. During the height of the storm, when the windspeed approached 15 m/s the bubble plumes reached all the way to the bottom.*

RELATED PROJECTS

This project represents a component of the ACOMMS MURI project lead by Jim Preisig from WHOI. The surface following float and associated acoustical resonators were successfully deployed from R/P FLIP and R/V Kilo Moana during September 2009 as part of the second RadyO field experiment (N000140610379 & N000140710754).

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- Vagle, S., and Farmer D.M., 1998, A comparison of four methods for bubble size and void fraction measurements, *IEEE J. of Oceanic Engineering*, 211-222.